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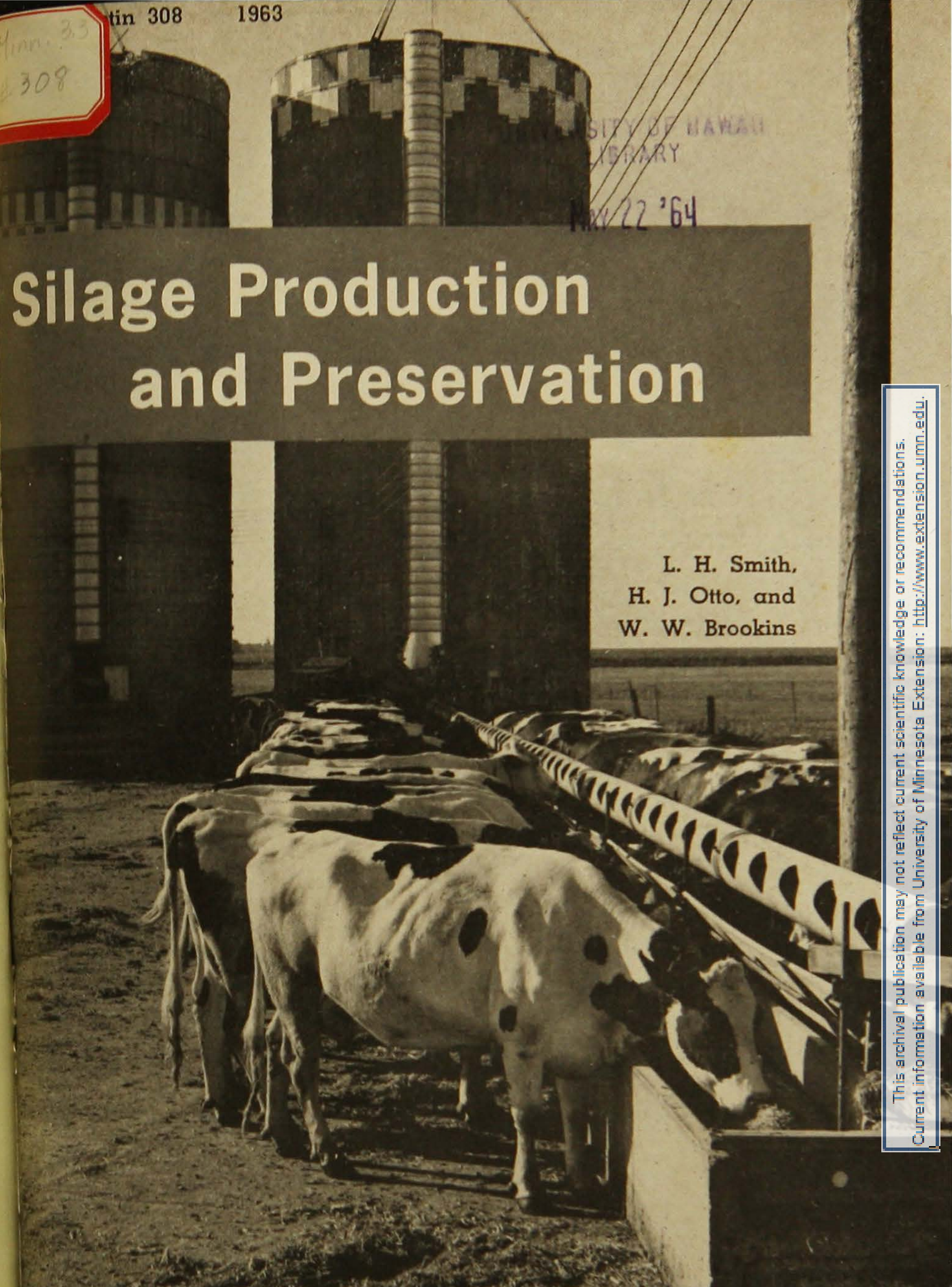

UNIVERSITY OF MINNESOTA
Agricultural Extension Service
S. DEPARTMENT OF AGRICULTURE

CONTENTS

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The Silage Process

Silage is the product resulting from the natural fermentation of moist plant material in the absence of air. The ensiling of plant material represents an attempt at preserving plant material at its highest quality for use during seasons when the fresh crop itself is not available.

In general, the process of silage production from green plant material takes place in this way:

1. When the crop is placed in the silo, it is still alive and respiring ("breathing") actively. The continued respiration of plant cells and micro-organisms forms carbon dioxide and heat. This results in the depletion of air and development of anaerobic conditions (without air) inside the silo.

2. Mechanical compression of the forage takes place as the cells die and as plant material accumulates in the silo. In some cases, depending on the kind of material ensiled and its moisture content, this leads to a flow of water from the silo (table 1).

3. Plant material in the field has many bacteria on its leaf surfaces. These bacteria increase inside the silo, using the nutrients present in the plant material for their food.

4. The fermentation of sugars, etc. in the plant by the bacteria results in the production of organic acids which lead to the preservation of the forage as silage. (This is similar to the production of alcohol by the fermentation of sugar by yeast.) Lactic acid is most commonly found in well-preserved silage. However, small quantities of acetic and propionic acid are often present as well.

5. If sufficient quantities of organic acids are produced, the plant material is preserved as silage. The material then has an acid content of approximately 1 to 2 percent of its fresh weight. The pH (degree of concentration of the acid) of the material is generally less than 4.2.

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To simplify terminology, trade names of products occasionally are used in this bulletin. No endorsement of products named is intended, nor is criticism implied of those not mentioned.

The above stages normally are completed in 17 to 21 days. However, the initial stages of carbon dioxide and heat production, leading to anaerobic conditions, normally are completed in the first 3 to 5 days.

At the end of approximately 3 weeks, the acidity of the mass determines whether the "silage" will remain stable and of good quality or will spoil.

If too few carbohydrates are present and bacteria cannot develop the proper amounts of organic acids needed to reduce the pH of the forage to less than 4.2, the following reaction may set in: Butyric-acid-producing bacteria will attack both the remaining soluble carbohydrate materials and the lactic acid which has already formed. This is accompanied by the breakdown of proteins with the formation of ammonia, carbon dioxide, and other compounds. There is a rapid rise in pH and a slimy, foul-smelling, "spoiled" silage results.

Problems in Silage Production

The problems of silage production from green plant material are often due to the following:

1. Too high moisture content—Moisture contents greater than 72 percent are common in crops harvested at immature stages of growth. This is due to the ability of living plant cells to retain water against leakage from the cell. When a plant cell is harvested and ensiled it is no longer able to hold water in excess of its natural water-holding capacity. Many plant materials can hold approximately 2.3 pounds of water per pound of dry matter at a pressure of 15 pounds per square inch (p.s.i.). This represents a moisture content of about

Table 1. Maximum water-holding capacities of various silage materials at 15 pounds per square inch pressure

Silage materials and additions	Moisture content, percent
Shelled corn (ground)	32-41
Corn cobs (ground)	61-68
Oats (ground)	44
Sugar beet pulp	73
Hays and straws	70-74
Alfalfa silage	68-72
Bromegrass silage (mature)	69
Corn silage	75

Source: Michigan State University data.

70 percent. Pressures at 15 p.s.i. and higher are commonly found in silos.

The amount of water which various plant materials can retain when stored in silos is given in table 1. Water contents greater than those which the dead plant material can hold are lost from the silo as seepage. This seepage carries with it many of the water-soluble plant nutrients present, so a sizable quantity of the sugars, simple proteins, and organic acids originally present in the green plant material is lost. These losses commonly are from 5 to 7 percent of the dry weight of the forage, and may run as high as 10 to 15 percent.

Water squeezed from the dead plant material carries various dissolved minerals with it. These minerals react chemically with the organic acids produced by the bacteria. Such reactions tend to "salt out" the acids so the acidity of the forage mass is not lowered and production of additional acid by the bacteria is required to lower the pH to the point where bacterial action is stopped. Since the production of organic acids by the bacteria in a silo requires carbohydrate materials, the "salting out" of the acids tends to greatly increase the amount of carbohydrates required for proper ensilage production.

It is generally true, therefore, that above a certain point, the wetter and more succulent the forage, the poorer the quality of silage which results. Moisture contents greater than those given in table 1 for an individual kind of material may be considered excessive.

These steps may aid in the production of high quality silage from high moisture plant material:

a. Wilt the crop to a more favorable moisture content. This is generally in the range of 60 to 70 percent moisture for such materials as fresh legumes and grasses.

b. Add additional carbohydrate materials to the forage to increase its carbohydrate content. This may not be successful; if water loss from the silo is great enough, soluble materials are largely lost with the water which escapes from the silo.

c. Add hay or straw to reduce the moisture content of the freshly harvested plant material to the desired range (table 3, page 10).

2. **Too much air**—The fermentation of carbohydrates, etc. to organic acids by bacteria will take place in the silo only when no air is present. Thus, the establishment of anaerobic conditions within the forage mass is essential for the preservation of the forage as silage. This depends largely upon the type and structural condition of the silo and the degree of compaction of the ensiled forage.

The forage mass must be tightly compacted so that no air can get into it. Air entrapped in the forage is rapidly used through plant and micro-organism (molds, yeast, bacteria, etc.) respiration, and anaerobic conditions prevail. However, if the forage cannot be compacted to the point where air is excluded, yeast, molds, and other organisms which require air (aerobic organisms) will increase. This often results in moldy silage.

Heating and spontaneous combustion may also take place if too much air is present. Significant losses in feeding value of the silage result from heating. As the temperature rises and the moisture is driven outward from the center of the mass many of the sugars and other carbohydrates are "caramelized." This results in a brownish colored silage which has a sweet odor resembling that of tobacco. However, much of the nutrient value, especially its vitamin content, is destroyed by "burning" of the forage, and the protein is greatly reduced in digestibility. In a Kansas test, protein digestibility was 67 percent for normal silage, 16 percent for brown silage, and 3 percent for black silage.

Thorough compaction of the forage is essential to high quality silage formation. Moisture content is a major factor influencing the degree of compaction of a forage mass. Difficulty is seldom encountered in establishing anaerobic conditions in a silo when the moisture content of the forage is greater than approximately 65 percent. At moisture contents of 50 to 60 percent the forage stems are bulky and hard, and fail to compact satisfactorily. This leads to a slow leakage of air into the forage mass if air is available in the silo. If the amount of air is somewhat limited molds, yeast, and other aerobic organisms frequently increase, leading to moldy, spoiled silage.

The establishment of anaerobic conditions in "dry" forages (moisture contents below 65 percent) requires considerable skill.

First the forage must be chopped as short as possible during harvest. A ¼-inch cut is best.

As the silo is filled, the forage should be distributed in a uniform layer which is slightly higher at the walls. The addition of two or three loads of high-moisture material as a cap to the silo will aid in the compression of the forage mass. Placing a plastic cover on the silo and sealing the doors will help keep out air.

If the forage is too dry (below 40 percent) for the above practices to establish airtight conditions, add water to bring it into a manageable range (50 to 70 percent moisture). As a rule of thumb, add 4 gallons of water per ton of green material for each 1 percent rise in moisture desired.

3. Too low carbohydrate level—In order for the silage process to "work," bacteria must produce organic acids which "pickle" the forage as silage. These organic acids are produced through a fermentation process from nutrients present in the ensiled plant material. The bacteria "charge" about 5 percent for the production of the desirable lactic and acetic acids. Thus, for each 10 pounds of sugar fermented about 9½ pounds of acid is formed. This is called fermentation loss, and represents the loss in feeding value of a crop due to ensiling. Fermentation loss represents nutrients used by the bacteria for their bodily functions; it is an unavoidable loss in the formation of silage.

In the formation of undesirable organic acids, such as butyric acid, the loss due to fermentation is approximately 25 percent. Thus, for each 10 pounds of carbohydrate fermented, only 7½ pounds of butyric acid is formed. The formation of butyric acid represents a sizable reduction in the feeding value of silage.

Simple sugars present in plant materials are most easily used by lactic-and acetic-acid-producing bacteria. Thus a high level of easily fermentable carbohydrates—such as the simple sugars—is essential to the production of high quality silage.

Silage Additives

Grasses and legumes often present difficulties in ensiling. Various substances may be added to the green plant material at ensiling to overcome these difficulties. The most common additives are preservatives and conditioners.

Preservatives

A silage preservative is a material which helps to develop acidity essential for preservation of the crop. There are two general types of preservatives in use: (1) substances which stimulate lactic acid fermentation through the addition of sugar or other readily fermentable carbohydrates, and (2) substances which minimize undesirable fermentation by inhibiting undesirable bacterial development.

The stimulation of lactic acid fermentation in silage is one of the best ways of controlling the changes in the silo. This is accomplished by adding carbohydrate-rich foodstuffs. The following substances may be used either alone or in mixtures for stimulation of lactic acid fermentation:

- Molasses, either dried or in solution.
- Ground cereal grains such as corn and cob meal, barley, and sorghum.
- Sugar beet pulp.

- Whey or lactose. The milk sugar (lactose) in the whey serves as a carbohydrate source for lactic acid fermentation.

These materials must be thoroughly mixed with the forage as it goes into the silo. This is often difficult with dry materials. With plant materials excessively high in moisture (over 72 percent) much of the added water-soluble carbohydrate may be lost because it is carried away with drainage of moisture from the silo.

Table 2 lists some suggested rates of application of the above preservatives.

High concentrations of organic acids commonly found in silage have a high feeding value for lambs and cattle. Addition of finely ground limestone (100 to 200 mesh) or feed grade urea, alone or in combination at the rate of 20 pounds per ton of green plant material,

Table 2. Pounds of preservative added per ton of green plant material

Plant material	Molasses	Phosphoric acid (75%)	Corn and cob meal	Ground corn, barley, or wheat	Dried whey*
	Pounds per ton of green plant material				
Legumes, fresh green:					
Alfalfa, red clover	80	20	200	150	40
Soybeans, Ladino clover	100	30	250	200	60
Legumes, wilted: All crops†	60	15	150	100	30
Legumes and grasses mixed, after grass is headed out:					
Fresh green	80	20	200	150	40
Wilted†	60	15	100	100	30
Legumes and grasses mixed, before grass is headed out:					
Fresh green†	60	15	100	100	30
Wilted	None	None	None	None	None
Grasses and cereals before heading out:					
Fresh green	60	20	200	150	40
Wilted†	40	10	100	100	30
Grasses and cereals after heading out:					
Fresh green†	40	10	100	75	20
Wilted	None	None	None	None	None

* Concentrated whey may also be used, applying two to three times the weight indicated for dry whey. Liquid whey can be used only with wilted crops, but may be added at 10 times the rate indicated for dry whey, as a means of utilizing the product.

† Preservatives may be omitted when the silos are smooth and airtight, and when good silo filling methods are carefully followed.

will increase the acid content of the silage. The use of urea also increases the protein content of silage for cattle and lambs.

Additional carbohydrates must be added if limestone or urea are used with ensiled crops low in carbohydrates (such as hay crops). This increases the acid content of the silage. Additional carbohydrate materials are not required when adding to corn or sorghum silage, since these crops have a high carbohydrate concentration.

Some preservative substances inhibit development of unwanted bacteria by minimizing undesirable fermentation. They are often mildly antiseptic and quickly lower the pH of the forage mass. Examples of this type are: sodium metabisulfite; sulfur dioxide gas; a mixture of calcium formate and sodium nitrate; and strong acids such as sulfuric, hydrochloric, and phosphoric.

Sodium metabisulfite contains 65 to 67 percent sulphur dioxide by weight and is very soluble in water. The action restricts fermentation by rapidly lowering the pH of the forage mass. It also aids in producing anaerobic conditions because it uses large volumes of oxygen.

For best results with sodium metabisulfite, apply 8 pounds per ton continuously and uniformly to chopped forage at the blower or as the forage is chopped by the forage harvester. The compound is marketed under many brand names. Its effectiveness decreases rapidly when the moisture content of plant material is above 72 to 75 percent. This is probably caused by leaching of the chemical from the forage.

Direct acidification—The major factor in determining the successful ensiling of a crop is the acidity which develops. Lactic acid bacteria are dominant under proper conditions in the silo because they can withstand relatively high concentrations of acid, compared to other bacteria. So if the acidity of the mass in the silo can be raised rapidly, the possibility of the development of spoilage-causing bacteria is reduced.

Addition of acids directly to ensiled forage to preserve it as silage dates back to 1885. In 1929 Virtanen and co-workers in Finland employed a mixture of acids (chiefly hydrochloric and sulfuric) to reduce the pH in the forage to 3.0 to 4.0. The feed was unsuitable for livestock when the pH was below 3.0. Above pH 3.0 the silage preserved in this manner was excellent both in feeding value and appearance.

Other acids used more recently include phosphoric acid and mixtures of hydrochloric and phosphoric acids. Organic acids such as lactic, acetic, and formic acids also have been used with success.

Direct acidification of silage has not been successful in this country largely because the acids are corrosive and farmers are unwilling to handle them.

Preservatives of Little Value

The following substances have proven to be of little or no benefit as silage preservatives for forage crops.

- Chemicals, including common salt, acid salts, carbon dioxide (either as a gas or solid), trace minerals (zinc, copper, iron, manganese, etc.), carbon bisulphide, benzoic acid, borax, salicylic acid, formaldehyde, calcium formate, and others.
- Antibiotics as possible inhibitors of undesirable bacteria in the silo.
- Enzyme preparations to aid fermentation of carbohydrate materials.

The above list is not exhaustive. Consult the label of any preservative to determine the active ingredient in the mixture. County agricultural agents can advise on the value of the material as a silage preservative.

Conditioners

The use of various dry materials to absorb enough excess water to reduce the water content of the mass to 70 percent or less has been tried. Chopped old hay or straw, ground corn cobs, and chopped corn stover are examples of the types of material used. Table 3 indicates the waterholding capacities of various materials.

Table 3. Waterholding capacity of various silage materials and additions

Material	Pounds of water per pound of dry matter
Ground corn grain	0.65
Ground oats	0.77
Ground wheat	0.68
Corn cob	
coarse grind (½-inch)	1.59
medium fine grind	1.81
fine grind (1/16-inch)	2.13
Sugar beet pulp	2.75
Alfalfa hay	2.20
Fine mixed grass hay	2.22
Oat straw	2.47

Source: Michigan State University data.

The following calculation illustrates how to determine the amount of conditioner which must be added to arrive at a given moisture content:

> One ton of alfalfa-brome mixture at 80 percent moisture contains 1,600 pounds of water. The ensiled material is capable of holding only 68 to 72 percent moisture (table 1). Assuming 70-percent waterholding capacity (1,400 pounds per ton), 200 pounds of water per ton of green plant material must be absorbed. Ground straw has a waterholding capacity of 2.47 pounds of water per pound of dry weight. If the straw contains 10 percent moisture, there are 90 pounds of dry matter in 100 pounds of straw. Thus 100 pounds of straw will absorb approximately 222 pounds of water ($90 \times 2.47 = 222$). Therefore, to absorb 200 pounds of water, 90 pounds of straw would be required (200 pounds of water $\div 222 = 0.9$; 0.9×100 pounds $= 90$ pounds of straw) per ton of alfalfa-brome at 80 percent moisture.

Other combinations can be calculated by substituting the proper numbers in the above example.

Crops for Silage

Preservation of fresh green plant material to supply feed of high quality throughout the year has long been the goal of livestock producers. There is nothing magic about the forage that comes from the silo. The quality obtained is largely determined by the materials that went into the silo. The best possible fresh plant material properly ensiled makes the best silage.

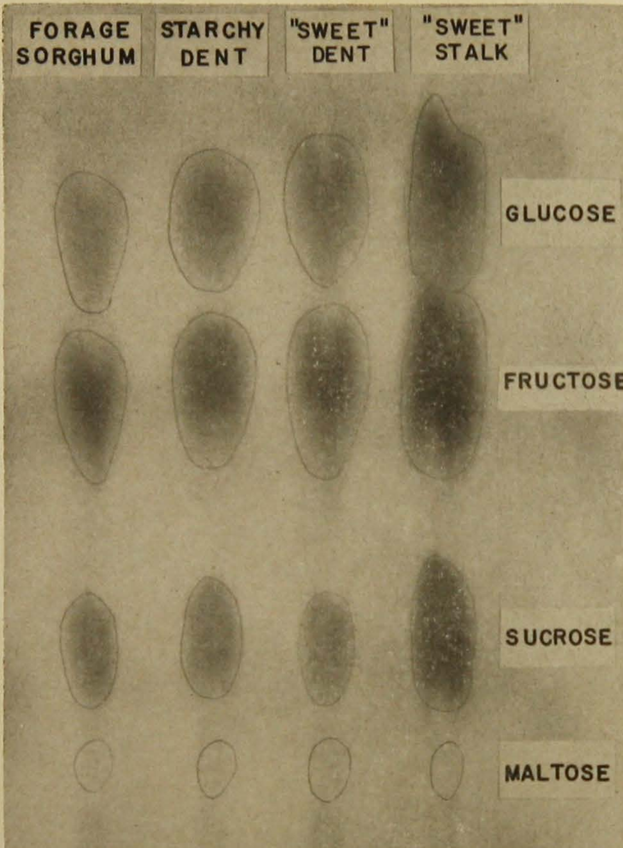
Corn

Corn has long been a major energy source for livestock in the United States. By harvesting the entire plant and storing it as silage farmers have been able to produce a high quality farm-grown feed.

Selection of plant material

Grain content of corn silage is an important factor in determining its feeding value. Hybrid corn which produces a high proportion of grain to stalks and leaves is preferred for silage. Avoid extremely large late corns which produce an extensive leaf area and stalk growth with a low proportion of grain.

Considerable interest has developed in varieties of corn which contain high concentrations of water-soluble sugars in the seed and in varieties which do not set seed but build up sugars in stalks and leaves. The photographs indicate the major types of water-soluble sugars in the ears, leaves, and stalk, of starchy dent (normal field corn), sweet dent, and sweet stalk corn (which fails to set seed). The in-



Amount of water-soluble carbohydrates present in ears and heads of four crops cut for silage is indicated by the size and intensity of the spots.

tensity of color and size of the spot provides an approximation of the quantities of the various sugars present. The amount of sugar, dry

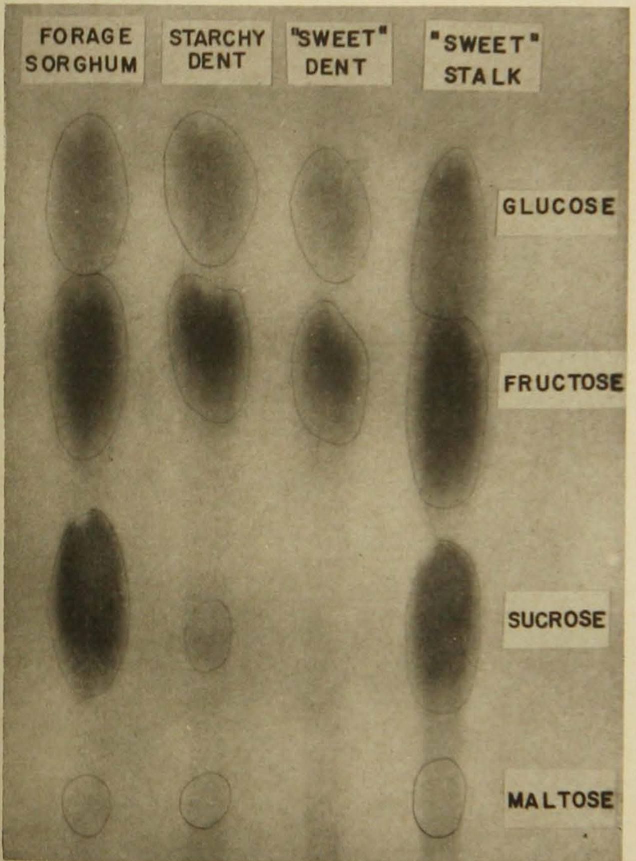
Table 4. Yield of dry matter and percent composition of sugar, protein, crude fiber, and TDN of varieties of corn harvested for silage

Crop	Dry matter yield, pounds per acre	Percent composition			Percent sugar	
		Protein	Crude fiber	TDN	Ear	Stalk and leaves
Starchy dent corn	9,959	9.24	18.38	72.83	0.52	0.50
Sweet dent corn	11,146	8.69	24.70	65.67	1.12	0.45
Sweet stalk corn	10,803	8.97	25.26	65.16	2.54	3.81

matter yield, and percent composition of protein, crude fiber, and TDN of the crops is reported in table 4.

Feeding trials with dairy cows failed to reveal any animal preference for the sweet stalk silage over the starchy corn silage. No sugars were present in either silage, the sugars having been converted to organic acids in the ensiling process.

Upon complete digestion of starch by an animal, the sugar *glucose* is released. So the benefit, if any, to be derived from "sugar" corns must come largely in the form of increased palatability. However, this factor also appears to be of minor importance, since little or no sugar remains in silage following the fermentation process.



Amount of water-soluble carbohydrates present in stalks and leaves of four crops cut for silage is indicated by size and intensity of the spots.

There appears to be little advantage in selecting silage corns for their content of sugar since the animal is able to digest and utilize both sugar and starch equally well.

Harvest

Evaluation of the fresh corn plant for maximum nutrient content and quality by means of animal feeding trials or chemical analysis is impossible under the average farm situation. Research indicates, however, that by harvesting the green plant material at the hard dough stage (grain fully dented) maximum yields of dry matter and a high quality product results.

Once the best fresh plant material available is harvested, conditions for good fermentation—correct moisture content, exclusion of air, and ample fermentable carbohydrates—must be met so that a high quality silage will result.

Moisture contents of 65 to 72 percent are optimum for silage production. Corn harvested at the hard dough stage contains approximately 70 percent moisture.

The exclusion of air in the silo depends upon compaction of the plant material. Corn harvested at the hard dough stage retains sufficient moisture so exclusion of air in the silo is complete and anaerobic conditions are quickly established.

An ample supply of readily fermentable carbohydrates is available in corn harvested at the hard dough stage.

Small Grains

Any small grain may be converted to high quality silage. Oats are more frequently used this way than other small grains because of their widespread availability, their high yield of forage, and their relatively low price as grain. Except for corn and hay, oats are produced on more acres and are more generally grown throughout Minnesota than any other crop.

Soils of high fertility may produce from 70 to 100 bushels of oats per acre or an equivalent 10 tons or more of silage. For every 7 to 8 bushels of grain a field is capable of producing, about 1 ton of silage can be expected.

Harvested as silage, the value of oats is greatly enhanced. In feeding value, oat silage is worth twice as much as the grain produced from an equivalent area. This forage is higher in energy value than hay crop silage. Protein content of the silage may be increased by sowing peas in a mixture with oats; for more information see Extension Bulletin 300, *Field Peas for Seed and Forage*. With or without peas in a mixture, oat silage compares favorably with corn silage as a feed.

Selection of Plant Material

Yields of oat silage vary according to season, area, soil fertility, stage of growth at harvest, variety, etc. Tests of oat varieties conducted at various locations in Minesota indicate that late-maturing varieties such as Rodney and Garry are best suited for silage production.

Harvest

Oat silage reaches its highest production of dry matter and protein per acre somewhere between milk and dough stage. The lapse of time between milk and dough stage is very short and delay in harvest results in loss of feed quality. Protein percent is highest at boot stage and drops rapidly after reaching the milk stage. Table 5 indicates the changes in composition of oat forage from boot stage to maturity.

Oats may be cut at various stages, but certain requirements must be met for proper silage development:

Before or at early flowering—Oats cut at this stage are high in protein, very high in moisture, and low in fiber. Wilt to 65 to 70 percent moisture or add preservatives in amounts given in table 2. Harvest at this stage results in considerably reduced yield and total digestible nutrients (TDN) as compared to later harvest.

Late milk or early dough stage—At this stage the forage is lower in protein and moisture but higher in fiber than at earlier stages. Moisture may still be too high for conventional silos. Wilt to 65 to

Table 5. Changes in composition of oat forage from boot stage to maturity at St. Paul, 1958

Stage of maturity	Moisture at harvest	Protein	Dry matter per acre
	percentage		tons
Boot	86.5	16.99	1.08
Head	82.7	14.59	1.52
Flower	78.1	11.63	1.91
Milk	72.3	12.28	2.16
Dough	67.1	8.42	2.88
Seed	58.6	8.06	2.62

Table 6. Forage yields (15 percent moisture) and percentage composition of forage sorghums and corn at silage stage*

Crop	Tons per acre at 15% moisture	Percent composition Crude fiber	Crude protein	TDN
Minhybrid 508 (corn)	6.0	18.4	8.6	73.3
Waconia Orange (sorgo)	7.8	27.8	7.6	62.5
Black Amber (sorgo)	4.4	27.5	8.5	63.1
FS-1 (DeKalb) (sorgo)	4.4	27.9	9.3	63.0
Kings Krost 145 (sorgo)	5.9	25.2	8.9	65.8
Neb. 301 (sorgo)	6.8	26.9	9.4	64.1
Orange Cane (sorgo)	4.6	30.2	8.6	60.2
Sorghum grass	6.0	35.9	8.5	53.8
Piper sudan grass	3.7	33.1	8.8	57.0

* Hard dough stage.

70 percent moisture, or add preservatives at about 75 percent of amounts given in table 2.

Mid-dough stage—Protein content is relatively low. Grain at the tip of the panicle is well advanced in the dough stage. The silage produced has a high energy value with a relatively high carbohydrate and fiber content. Direct cutting and packing in the silo is possible without the use of preservatives. Harvest at this stage of development results in highest yields per acre of any of the three alternatives.

Sorghums

Interest in forage sorghums as a silage crop has increased in recent years with the advent of hybrids and chemical weed control. The forage sorghums (sweet sorgos) are summer annuals that tolerate long, hot, dry periods. Under emergency conditions such as excessive soil moisture, delayed planting, or drought resulting in poor emergence of corn or small grain, forage sorghums will often produce a good crop in most areas of Minnesota when planted by the first week in June.

Selection of Plant Material

The grain content of forage sorghum, while not as high as the grain content of corn, is an important factor in the evaluation of sorghum silage. So select varieties for silage which produce a high proportion of grain to leaves and stalks. Research on varieties of forage sorghum conducted at Minnesota is reported in table 6.

Forage sorghums are generally higher in sugar content than are corns. However, once the plant is ensiled little sugar remains in the forage. The sugars are largely converted to organic acids during the fermentation process.

Feeding tests have indicated that forage sorghums have a somewhat lower feeding value than well-eared corn silage.

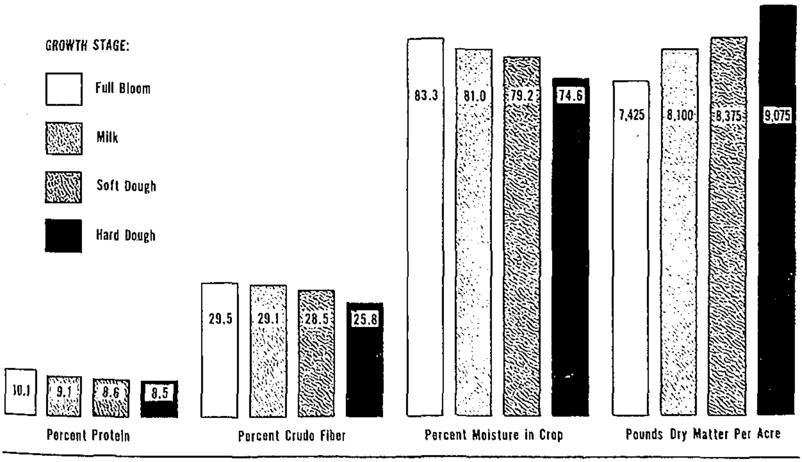
Harvest

The content of protein and crude fiber decreases with advancing maturity of the crop, while total dry matter production increases (see graphs). The percentage of leaves and stems decreases and the percentage of heads increases with advancing maturity. This emphasizes the importance of harvesting forage sorghums at the proper stage of growth.

Moisture contents of 70 to 75 percent are optimum for preservation of forage sorghums as silage. Higher levels are considered undesirable.

For silage, forage sorghums should be harvested when the kernels are in the hard dough stage for the following reasons:

1. The yield of dry matter is higher than at earlier stages of development.
2. There is a larger proportion of grain to leaves and stems than at earlier stages.



Changes in the composition of forage sorghums with advancing maturity of the crop.

3. The silage is more palatable than that made from more immature plants.

4. Moisture content is optimum for proper silage fermentation and preservation.

5. Crude fiber contents are lower than in forage harvested at earlier or later stages of maturity.

Grass and Legume Silage

The storage of grass and legume crops as silage has met with varying success by farmers around the world. There is much to recommend the storage of these crops as silage. Some advantages are:

- Reduced dependence upon weather, especially with first cutting.
- Reduced field losses of forage due to leaf shattering and weather damage.
- Often a higher vitamin A and protein content in silage than in similar material cured as hay.
- Greater ease of mechanical harvesting and feeding than with hay.

Three general types of silage, based on moisture content of the forage, are produced:

1. **Direct cut forage, high moisture**—The green plant material is often ensiled at 75 to 80 percent moisture. Silage resulting from this material is generally of low quality and feeding value. It often has a strong putrid odor due to a high content of butyric acid in the silage. The addition of preservatives such as molasses and ground grains and various chemicals frequently fails to preserve this material successfully. The ensiling of direct cut, high-moisture forage is extremely risky and should only be undertaken with the hazards well in mind.

2. **Wilted forage, medium moisture**—Green forage ensiled at 60 to 70 percent moisture content generally produces a silage of good quality and high feed value. There is seldom a high content of butyric acid in such silage. In general, the silage has rather sharp acid odor and green color, indicating a desirable fermentation has occurred. The scorecard in table 8 indicates the relative importance given to color and preservation in quality of hay crop silages.

3. **Haylage, low-moisture forage**—Green forage ensiled at moisture contents from 40 to 60 percent usually produces a high quality

product. However, certain precautions must be observed when ensiling this material. The complete absence of air in the silo is essential to avoid severe reduction in feeding value and quality to the forage from heating and the growth of molds.

In sealed storage units the exclusion of air from forage usually presents no problem. However, when forage containing less than 60 percent moisture is placed in a conventional upright silo the mass must be carefully compacted to exclude air. Chopping the forage as short as possible, careful distribution and packing when filling, and the addition of two or three loads of direct-cut high moisture material to the top of the silage are aids in producing airtight conditions within the silo. The use of plastic at silo doors and as a cap also aids in reducing air infiltration after filling.

Selection of Plant Material

Selection of hay crops for silage should be based on crop quality and quantity. A well-managed alfalfa-brome crop often provides a high quality, high yielding hay crop for silage. Other crops such as sudan grass, millets, native and cultivated grasses, and most grass-legume mixtures have also been ensiled successfully.

Harvest

The grass and legume silage scorecard in table 9 indicates the stage of growth at cutting preferred for best silage quality. Minnesota research (table 7) emphasizes the importance of early harvest for high

Table 7. Composition of alfalfa-grass mixtures harvested at different dates and growth stages, average of 19 locations in Minnesota, 1960-62

Cutting date and stage of growth	Composition, %		
	TDN*	Fiber	Protein
First cutting			
June 1 (prebud)	68.4	25.8	20.0
June 14 (late bud-1/10 bloom)	60.3	32.2	16.6
June 23 (½ bloom)	57.4	34.5	15.1
July 1 (full bloom-mature)	54.0	37.0	13.2
Second cutting			
6-8 weeks regrowth	59.0	32.3	16.7
Third Cutting			
5-6 weeks regrowth	67.0	27.1	19.2

* TDN is calculated by formula from protein and fiber.

quality silage. In the 30-day range of date of first cutting, from June 1 to July 1, the quality of the forage changed as follows:

Crude fiber—Gain of 11.2 percent, or 0.37 percent per day.

Crude protein—Loss of 6.8 percent, or 0.22 percent per day.

Total digestible nutrients (TDN)—Loss of 14.4 percent, or 0.48 percent per day.

These and other studies indicate that the quality of the forage and subsequent silage decreases with advancing maturity of the forage.

Grain Silage

Almost any kind of grain can be stored successfully in a silo if certain conditions are met: (1) proper moisture content must be maintained, (2) good storage structures must be provided, and (3) grain must be handled properly.

However, the advantages for storing small grains in the silo are not so clear-cut as for corn. Timely harvest of dry grain is not nearly so difficult with small grains as with corn.

Ear and Shelled Corn Silage

There are several advantages in storing corn in the silo compared to storing it in the crib or bin.

➧ Corn with high moisture content can be stored safely. This allows earlier harvest when full-season-maturity hybrids are grown. Since harvesting operations can be completed at an early date, more time is available for fall plowing before the soil freezes. In years when corn does not mature at normal dates, it can be stored in the silo without fear of spoilage.

➧ Crop savings can result from lower field losses. Research has shown that harvesting losses increase as moisture content decreases below 30 percent. In this moisture range corn is difficult to store in conventional cribs without artificial drying. As corn becomes dry, stalk breakage and lodging increase; early harvest helps minimize losses from these causes.

➧ A season's feed grinding can all be done at one time. This increases labor efficiency.

➧ Production of full-season-maturity hybrids is possible. Because such hybrids utilize the full growing season, they produce higher average yields than earlier maturing hybrids. However, select only hybrids early enough in maturity to produce their maximum dry weight before a killing frost.

The method is adapted to mechanized handling and feeding operations. There are certain limitations of storing corn grain in the silo:

More weight per unit of feeding value must be handled because of the higher water content as compared with dry grain.

The corn grain silage storage method can be used only by the livestock feeder—not by the cash grain farmer.

When corn is stored in stave silos, enough livestock must be fed to allow feeding at least 3 inches off the top each day in warm weather.

Freezing is sometimes a problem because of the high moisture content.

Storage Structure

Ear and shelled corn silage can be stored in any upright silo that is in good condition. The silo must be airtight to prevent spoilage. The doors should be sealed with plastic or other material to prevent air leaks. The top should be covered with plastic film to reduce spoilage.

Some silos may need reinforcement. Masonry silos built for whole plant silage may need additional hoops to hold corn grain silage. For such silos, add one extra hoop between each existing hoop in the center one-third of the silo and place extra hoops between doors to eliminate spreading. Your silo dealer or county agent can advise you on the need for extra hoops on your silo.

Moisture Content

Good quality silage can be produced from shelled corn at 30 percent moisture and from ear corn at 30 to 35 percent kernel moisture in stave silos. Lower moisture content is acceptable in sealed-storage units. At 30 to 35 percent kernel moisture the whole ear is about 5 percent higher in moisture than the grain. Consequently, such ear corn silage contains 35 to 40 percent moisture.

Since moisture content is very important in making high quality silage, be sure to check it carefully.

If the moisture content is below the above figures, water can be added. As a rule of thumb, 4 gallons of water should be added to each ton of green material for each desired 1 percent increase in moisture.

Preparation of Corn

Corn should be coarsely ground for highest silage quality. A hammer mill or burr mill can be used for grinding shelled corn, but ear corn should be cut into short lengths before grinding. Special mills which combine cutting and grinding actions are available.

Grinding the corn assures highest feeding value and helps reduce possibility of spoilage in the silo and during feeding operations.

Feeding

Top spoilage while feeding from the silo is no particular problem when the air temperature is below 50° F. When the temperature is above 50° F., about 3 inches should be fed from the top of conventional silos per day. In sealed silos, top spoilage is not a problem.

Well-packed ear corn silage averages about 50 pounds per cubic foot at 35 percent moisture. At 30 percent moisture, shelled corn averages 60 pounds per cubic foot.

The number of tons of silage in the silo can be determined from the following formulas:

For ear corn at 35 percent moisture:

.0196 × (silo diameter in feet) × (silo diameter in feet) × (depth of silage in feet) = tons ear corn silage

For shelled corn at 30 percent moisture:

.0235 × (silo diameter in feet) × (silo diameter in feet) × (depth of silage in feet) = tons shelled corn silage

Silage is less dense at the surface than in the depths of the silo. Hence, the following formula must be used to determine the amount of silage at the surface:

2.42 × (silo diameter in feet) × (silo diameter in feet) = pounds ear or shelled corn silage per inch of depth.

The number and class of livestock to be fed, the size of the silo, and the amount of silage fed per day must be considered when deciding whether to use this method of storing corn.

Ear and shelled corn silages have about the same feeding value as their dry counterparts on an equal dry matter basis. There are some reports of slightly faster and more efficient gains from beef cattle on ground ear corn silage than on dry ground ear corn. In some cases these differences might be accounted for by greater palatability and consequently greater silage consumption.

Evaluation of Silage Quality

Silage quality is related to its ability to produce meat, milk, or fiber when fed to the animal. Obviously, animal feeding trials are the best test of silage quality. But such trials are expensive and require a great deal of care and evaluation for reliable results, and are not possible for "on-farm" silage evaluation.

Chemical tests are another method of estimating silage quality. The tests most commonly used are called the "feed analysis" or "proximate analysis" tests. They measure the following compounds or groups of compounds in silage:

Digestible fractions—(1) protein, (2) crude fat, (3) ash or mineral content, and (4) nitrogen-free extract (largely carbohydrate materials).

Nondigestible fraction—Crude fiber.

Silage rated good (low fiber and high protein, fat, and nitrogen-free extract) or poor (high fiber and low protein, fat, and nitrogen-free extract) by chemical tests are also good and poor respectively in animal performance. Chemical tests require a trained chemist and special laboratory equipment, and are not adaptable to the "on-farm" estimation of silage quality.

Another chemical test called the "artificial rumen" is extensively used in estimating quality of silage and other forages. In this test a sample of rumen fluid is mixed with the forage to be tested and held at a constant temperature for a period of time. Natural enzymes and bacteria in the rumen fluid then digest the "digestible" portion of the forage leaving the nondigestible portion behind. This analysis is not adapted to "on-farm" evaluation of forages.

A general estimation of silage quality can be made by a careful inspection of the silage. Scorecards which serve as guides to silage evaluation are given in tables 8 and 9. One sample of silage will not necessarily be representative of the entire silo content—there is much variation due to location in the silo, separation in the silo when filling, and difference in the material ensiled.

Corn Silage

Major points to consider in the physical evaluation of corn silage for quality are: grain content, color, and odor.

Grain Content—Preservation being equal, corn silage with a high grain content makes livestock feed superior to corn silage with little or no grain. One hundred pounds of "high grain" silage may contain 20 to 21 pounds of digestible nutrients, while "low grain" silage at the same moisture content may contain only 15 to 16 pounds of digestible nutrients. Plant adapted high-yielding hybrids for silage that produce strong, vigorous plants with high grain content.

Color—A natural green is most desirable. While slight variations from this are not serious, brown, yellow, or strongly faded colors are seriously criticized.

Table 8. Corn silage scorecard

CROP QUALITY (50 points) BASED ON GRAIN CONTENT	Possible score
1. **HIGH** proportion of corn grain to stalks and leaves	46-50
2. **MEDIUM** proportion of corn grain to stalks and leaves	36-45
3. **LOW** proportion of corn grain to stalks and leaves	26-35
4. **NONE** (either no corn ears have developed or ears have been removed)	20-25
PRESERVATION (50 points) BASED ON COLOR AND ODOR	
A. COLOR (25 points)	
1. **DESIRABLE**—Natural green to olive green color	21-25
2. **ACCEPTABLE**—Yellowish green to slight brownish. If frosted, faded light yellow. Slight mold spots evident	11-20
3. **UNDESIRABLE**—Deep brown or black indicating excessive heating or putrefaction. Predominantly white or gray indicating excessive mold development	5-20
B. ODOR (25 points)	
1. **DESIRABLE**—Clean, pleasant odor with no indication of putrefaded light yellow. Slight mold spots evident	11-20
2. **ACCEPTABLE**—Yeasty and fruity indicate a slightly improper fermentation. Slight burnt, sweet, carmelized, or musty odor indicates excessive air. Quite rank or sour indicates high moisture	11-20
3. **UNDESIRABLE**—Strong burnt odor indicates excessive heating. Putrid odor indicates improper fermentation. Very moldy or musty odor with excessive mold visible throughout the silage	5-10
TOTAL SCORE	100

SCORING: Excellent silage 90-100, good silage 76-89, fair silage 60-75, poor silage below 60.

Deep brown or charred black indicates excessive air in the silage mass, resulting in high temperatures and a serious loss of feeding value of the silage.

Yellow or faded color, often resulting when corn is ensiled after frost, indicates a heavy loss of carotene. When there is sufficient moisture for good packing, the feed value, except for carotene, may be good in spite of the color.

Molds—white, gray, or pink molds, when present in appreciable amounts, indicate loss of feed value and should be penalized in proportion to the amount present. Corn kernels should retain a bright yellow color.

Odor—Good corn silage has a clean, slightly sharp odor and taste, indicating a proper amount of acidity for preservation.

Silages with fruity odors should be penalized, but not severely.

Strong, musty, moldy, or burnt odors are undesirable. They may indicate serious feed loss and should be heavily penalized.

High moisture corn silage, often found in the bottom of poorly drained silos, may have a strong, sour odor. This is not desirable, but *if livestock consume the silage it is still acceptable.*

Grasses and Legumes

The evaluation of grasses and legumes for silage is similar to that for corn silage. The major points to consider are color, odor, and stage of growth at harvest.

Stage of Growth—Forages, both grass and legumes have higher digestibility and contain more protein in the early stages of growth. Alfalfa should be harvested by early bloom stage, clovers by one-half bloom stage, and the grasses before flowering, for highest quality and and good yield in terms of milk or useful feed nutrients per acre. Late-cut, mature, stemmy forage (even though well preserved) cannot make high quality feed.

Although weeds and stubble may be well preserved, the total amount of nutrients per acre will be reduced due to lower quality and yields. Although not listed in this scorecard, samples with high foreign matter content should be penalized.

Color—Natural rather than artificial light should be used in grading samples on color.

A natural color is desired and slight changes should not be seriously penalized.

Dark brown or charred black is an indication of excessive heating. This is usually caused by poor packing or material with too low moisture content. Silage on the outside of silage stacks is usually this color, even where the forage was of high moisture when stacked.

Deep green or black is often seen in very high moisture silage. It is sometimes associated with strong odors and occasionally with a slippery, slimy feel which is seriously objectionable.

Molds indicate a feed loss and are caused by air. To prevent molding, use higher moisture material, pack better, or provide a cover of plastic film, sawdust, or soil.

Odor—Silage odors range from a very mild crushed grass smell to very strong and penetrating. Odor reflects the type of silage fermentation.

While silages with strong odors often are objectionable to people who must handle them, they may still be good feed and readily eaten by livestock. These objectionable silages, however, should not be kept in storage for too long a period. They must be fed carefully to prevent off-flavors in milk.

Strong ammonia and moldy or musty odors indicate considerable loss in feed value and should be heavily penalized. Reserve the de-

Table 9. Grass and legume silage scorecard

CROP QUALITY (40 points) BASED ON STAGE OF GROWTH AT CUTTING	Possible score
1. Before blossom or early heading (fine stems, high leaf content)	36-40
2. Early blossom	31-35
3. Mid-to-late bloom	21-30
4. Seed stage (very stemmy, coarse, low leaf content)	10-20
PRESERVATION (60 points) BASED ON COLOR AND ODOR	
A. COLOR (30 points)	
1. DESIRABLE—Natural forage green or slightly yellowish green. Light to dark green depending on crop and/or additive used. Red clover may have a darker color	26-30
2. ACCEPTABLE—Deep dark green, very yellowish green, or slight brownish green	16-25
3. UNDESIRABLE—Brown or black indicating excessive heating or putrefaction. Predominantly white or gray indicating excessive mold	5-15
B. ODOR (30 points)	
1. DESIRABLE—Clean, pleasant with no indication of putrefaction	26-30
2. ACCEPTABLE—Somewhat strong, yeasty, fruity or musty, slight burnt odor, sweet	16-25
3. UNDESIRABLE—Strong, burnt, or carmelized odor indicates excessive heating. Sliminess and a putrid odor inimproper fermentation. Very musty or moldy odor with excessive mold visible	5-15
TOTAL SCORE	100

MOISTURE CONTENT: High moisture silage (75 percent or above) contains less feed value per pound than lower moisture silage. High moisture may indicate excessive juice loss with loss of nutrients. However, heavy nutrient loss may result from ensiling material too dry to pack well. Moisture content can be approximated by squeezing in the hand, if juice runs freely it is high moisture.

SCORING: Excellent silage 90-100, good silage 76-89, fair silage 60-75, poor silage below 60.

sirable rating for silages with no strong, objectionable odors. High-moisture silages are usually the ones with the strong odors.

Addition of preservatives or careful wilting may insure a proper fermentation and a desirable odor.

Procedures for Silage Evaluation

To evaluate silage, select enough randomly taken samples to fill a bushel basket. Mix thoroughly and take a 2-quart sample, then mix again and take a sample for evaluation.

The actual scoring procedure is one of close inspection of the silage for the factors discussed above. In general, excellent quality silage should score between 90 and 100, good silage 76 to 89, fair silage 60 to 75, and poor silage below 60.

A continued observation of the silage, using the evaluation based on this scorecard, will help to adjust feeding practices and possibly help make better silage the next year.

SILAGE IS WELL ADAPTED TO MECHANICAL FEEDING

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